OCE2

(Ocean Color Experiment 2)

~ *Systems Presentation* ~

IDL Systems Engineering

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April 27, 2012

Total Instrument Rack-up
(no contingency included)

Instrument Synthesis & Analysis Laboratory

OCE2 Ocean Color Experiment Version 2	Total Mass	Total Operating Power (Effective Average)	Total Data Rate
OCE2 Scan Drum Assembly Scanning Telescope Assembly Drum Housing Scan Drum Motor / Encoder Half Angle Mirror Assembly Half Angle Mirror Motor / Encoder Momentum Compensation Assembly Momentum Compensation Motor/Encoder Momentum Compensation Wheel Momentum Compensation Wheel Housing Cradle Assembly Cradle Structure Tilt Mechanism Bracket Tilt Mechanism Motor 1/ Resolver Tilt Mechanism Motor 2/Resolver Calibration Target Assembly Calibration Target Stepper Motor / Resolver Main Electronics Box Mechanism Control Electronics Box Launch Locks (HOP) For Tilt Mechanism- Starsys EH-1540 Aft Optics/Detector Assembly Aft Support Structure Lens/Detector "Six Pack" Assembly Fiber Optics Silicon PIN Photodiode InGaAs PIN Photodiode Preamp, FET switches, FET driver Digitizer Electronics Box Thermal Subsystem	**xx.x kg** *Details on page xx*	**~448 W** **Average** *Details on Pages* *Ops/Survival Heater Power Summary on pages xx*	**Average Data Rate = 7400 kbps** *Details on Page xx*

OCE2 Study Parameters

- **Delivery Date: 6/2018**
- **Orbit:**
  - Thermal Analysis assumes 11:00 AM descending crossing
  - Goal: Noon equatorial crossing time and altitude of ~700 km
- **Mission Class: C (with selective redundancy)**
- **Mission Duration: 3 to 5 years**

Operational Concept

- **Continuous scanning**
  - Raster scan with +/- 51 deg cross track science view
  - Global coverage in two days
  - IFOV 1 km^2 +/- 10%
- **Sunlit portion of orbit, +/- 70 deg lat.,**
- **Solar calibration viewing when available during orbit (at terminator crossings) 1x per day**
- **2x orbit inst. tilt pointing (ala SeaWiFS) to +/- 20 deg. for sun glint avoidance (minimization)**
- **monthly S/C slews for Lunar calibration scans**

Forward and Aft Scans Switched at Sun Zenith

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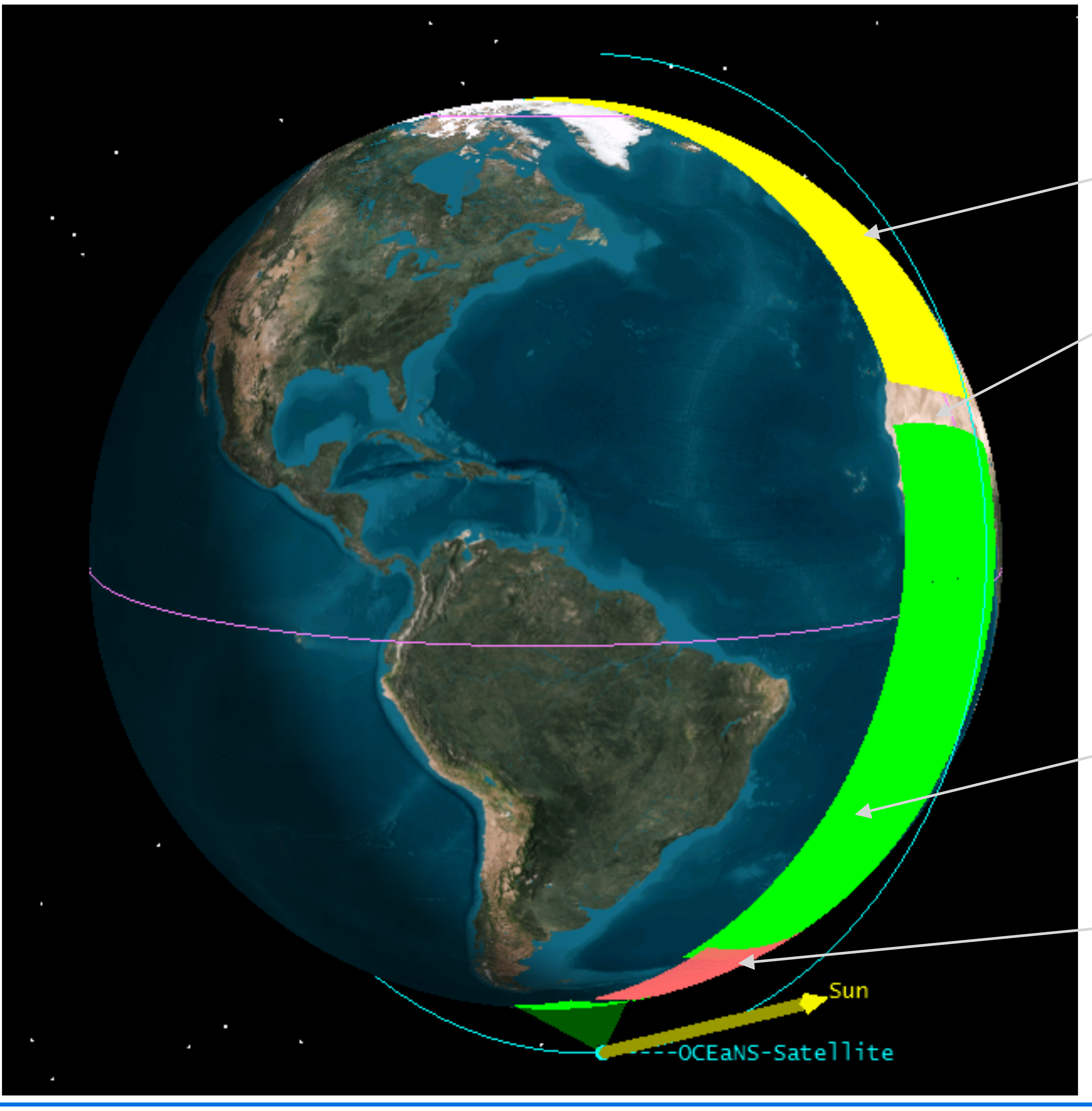

Aft Scan

Switch at Sun Zenith

Forward Scan

Cal. Scan

Forward and Aft Scans, One at a Time, Just Past Sun Zenith Switchover

Augmented Table 1 (cont'd)

#	User	λ	BW (FWHM)	Spatial Res.	L_{typ}	L_{max}	SNR
		nm	nm	km^2	mW / cm^2 - sr - µm		
1	Oceans	350	15	1 x 1	7.46	35.6	300
2	Oceans	360	15	1 x 1	7.22	37.6	1000
3	Oceans	385	15	1 x 1	6.11	38.1	1000
4	Oceans	412	15	1 x 1	7.86	60.2	1000
5	Oceans	425	15	1 x 1	6.95	58.5	1000
6	Oceans	443	15	1 x 1	7.02	66.4	1000
7	Oceans	460	15	1 x 1	6.83	72.4	1000
8	Oceans	475	15	1 x 1	6.19	72.2	1000
9	Oceans	490	15	1 x 1	5.31	68.6	1000
10	Oceans	510	15	1 x 1	4.58	66.3	1000
11	Oceans	532	15	1 x 1	3.92	65.1	1000
12	Oceans	555	15	1 x 1	3.39	64.3	1000
13	Oceans	583	15	1 x 1	2.81	62.4	1000
14	Oceans	617	15	1 x 1	2.19	58.2	1000
15	Oceans	640	10	1 x 1	1.9	56.4	1000
16	Oceans	655	15	1 x 1	1.67	53.5	1000
17	Oceans	665	10	1 x 1	1.6	53.6	1000
18	Oceans	678	10	4 x 4	1.45	51.9	2000

Ref: PACE Ocean Measurement Requirements V10-d.docx & Measurement_Requirement_OES_Atmo_17Apr12.docx

Augmented Table 1 (Cont'd)

#	User	λ	BW (FWHM)	Spatial Res.	L_{typ}	L_{max}	SNR
		nm	nm	km^2	mW / cm^2 - sr - µm		
19	Oceans	710	15	1 x 1	1.19	48.9	1000
20	Oceans	748	10	1 x 1	0.93	44.7	600
21	Oceans	765	40	1 x 1	0.83	43	600
22	Oceans	820	15	1 x 1	0.59	39.3	600
23	Oceans	865	40	1 x 1	0.45	33.3	600
24	Oceans	1245	20	1 x 1	0.088	15.8	250
25	Oceans	1640	40	1 x 1	0.029	8.2	180
26	Oceans	2135	50	1 x 1	0.008	2.2	100
27	Atmos	940	15	1 x 1	0.78	21	150
28	Atmos	1378	10	1 x 1	0.35	9.5	100
29	Atmos	2250	50	1 x 1	0.07	2.1	150
30	Atmos	2250		.25 x .25			
31	Atmos	865		1 x 1			
32	Atmos	865		.25 x .25			
33	Atmos	1640		1 x 1			
34	Atmos	1640		.25 x .25			
35	Atmos	2135		1 x 1			
36	Atmos	2135		.25 x .25			
37	Atmos	763		1 x 1			
38	Atmos	763		.25 x .25			

Ref: PACE Ocean Measurement Requirements V10-d.docx & Measurement_Requirement_OES_Atmo_17Apr12.docx

Optical telescope Parameters

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Effective Focal length (mm)	520.36
F/#	2.89
Plate scale	1 km / fiber core (0.8mm)
FOV	1° × 1°
Wavelength range (nm)	350 - 2400
Pupil Diameter (mm)	180

Telescope layout

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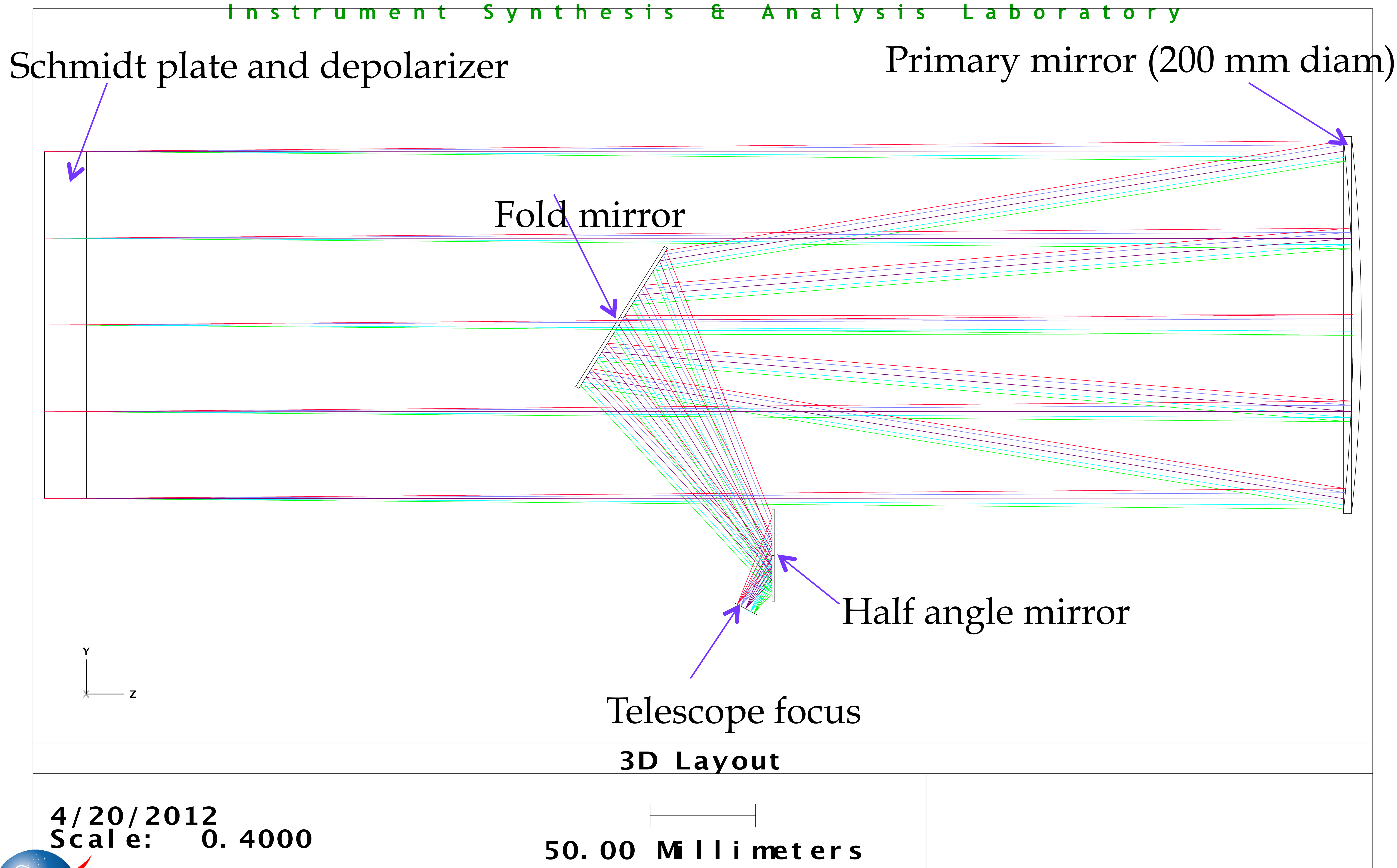
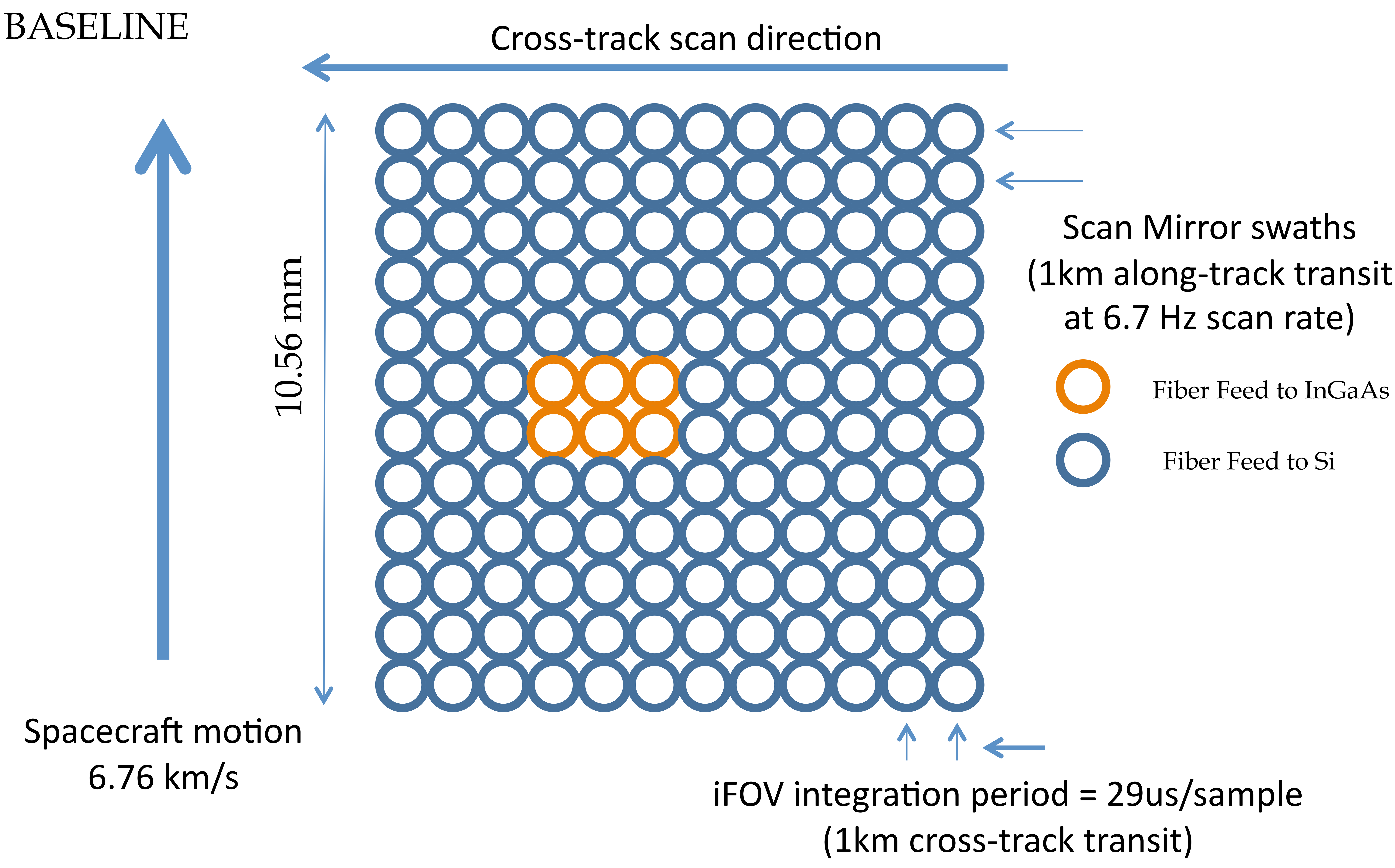


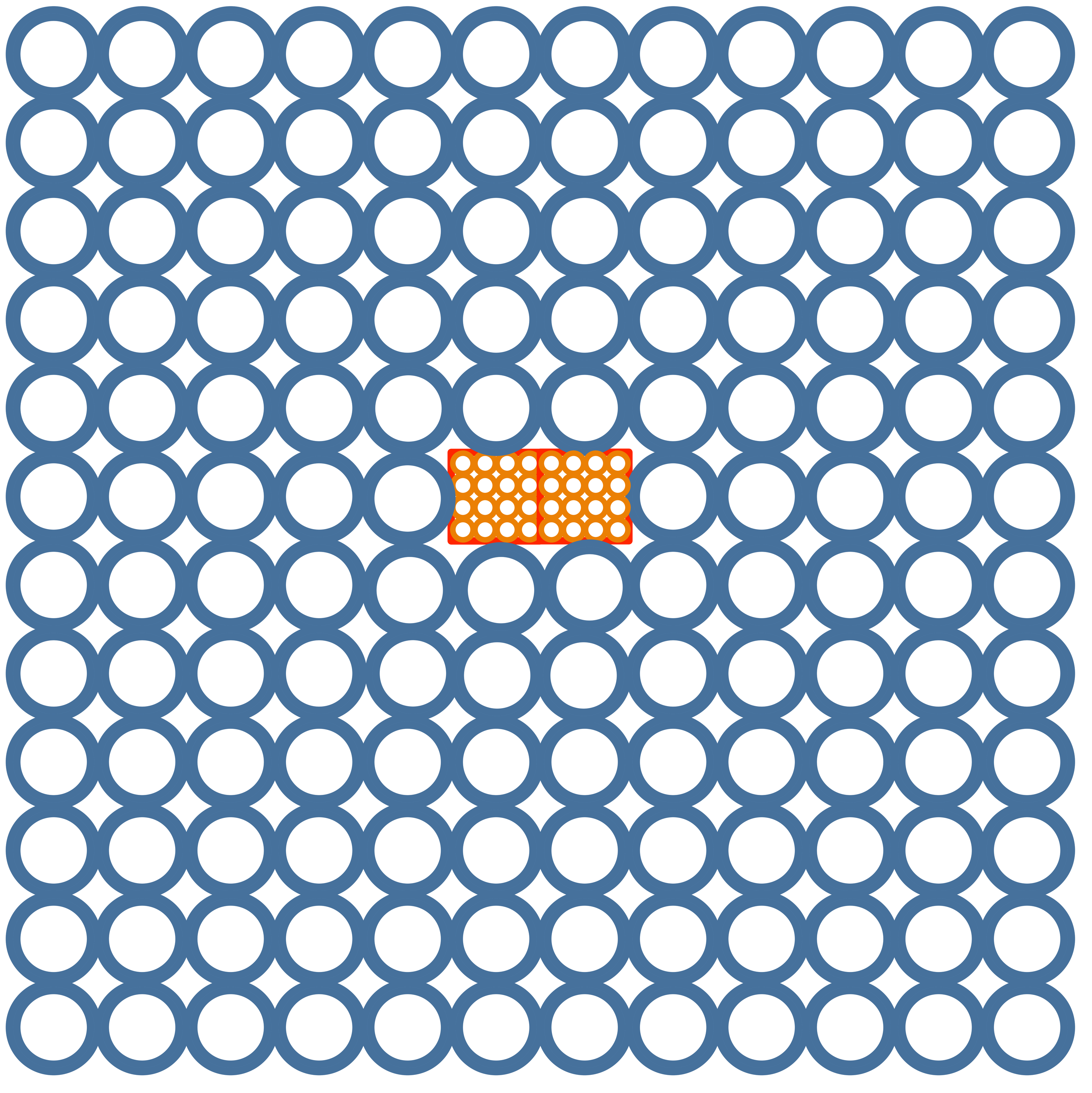
Focal plane image = 12x12 Fiber array – 800(ID)/880(OD)um ea.
Each Fiber core (800um) = 1km dia. GSD (iFOV)
=> 144 measurement channels



Focal plane central image = 4x4 fiber array (x4) 200(ID)/ 220(OD)um fibers = 250m sampling over 4km^2 (λ_1)

Delta Option (to be examined in study extension)

142+32=174
Total Channels

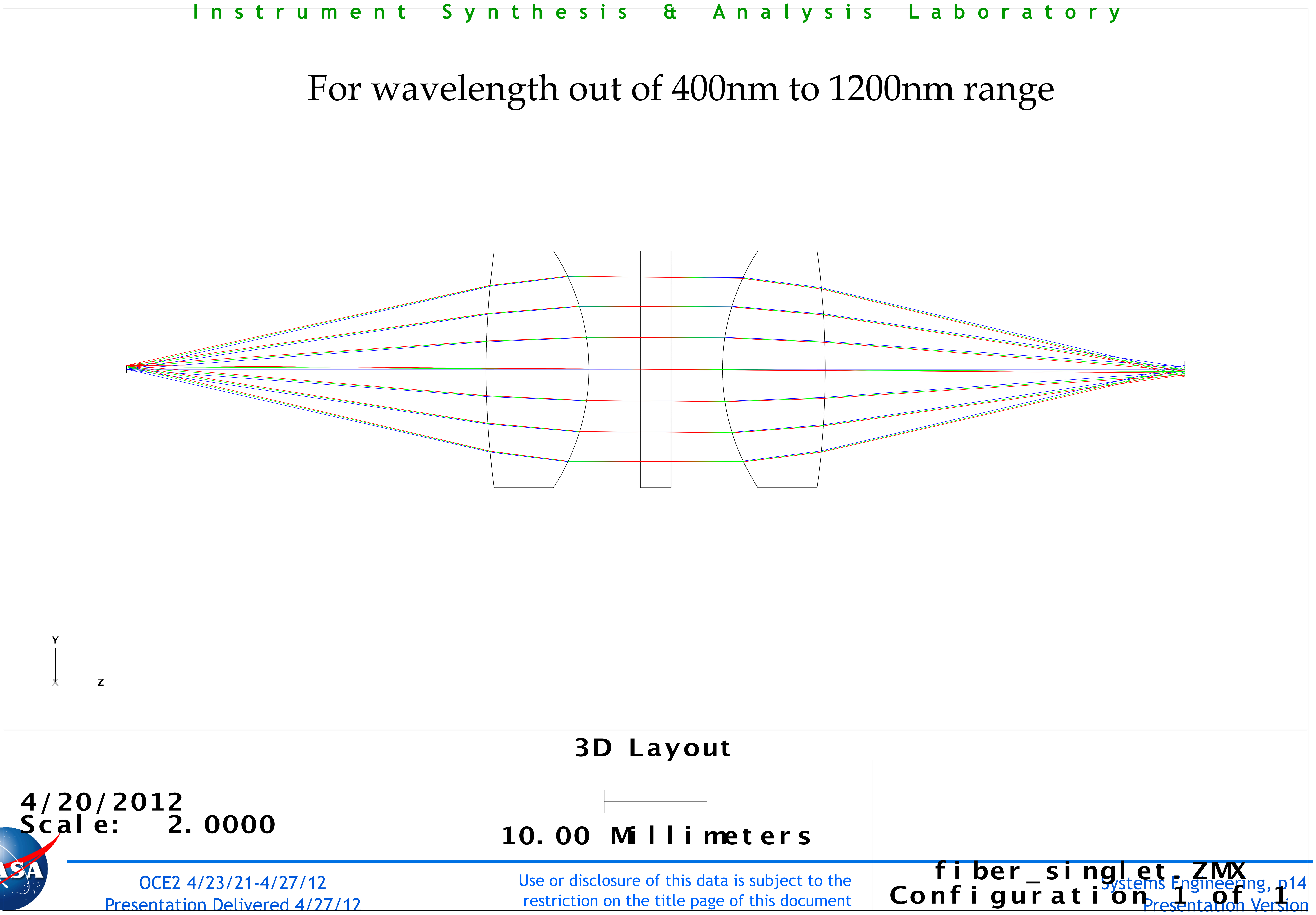


Detector Plane Optics

- **Singlet (Baseline)**
  - Higher throughput
  - More manual tuning
- **Doublet (Option)**
  - Lower throughput
  - Lesser/no tuning

Fiber Receiver Optics (Singlet)

For wavelength out of 400nm to 1200nm range



OCE2

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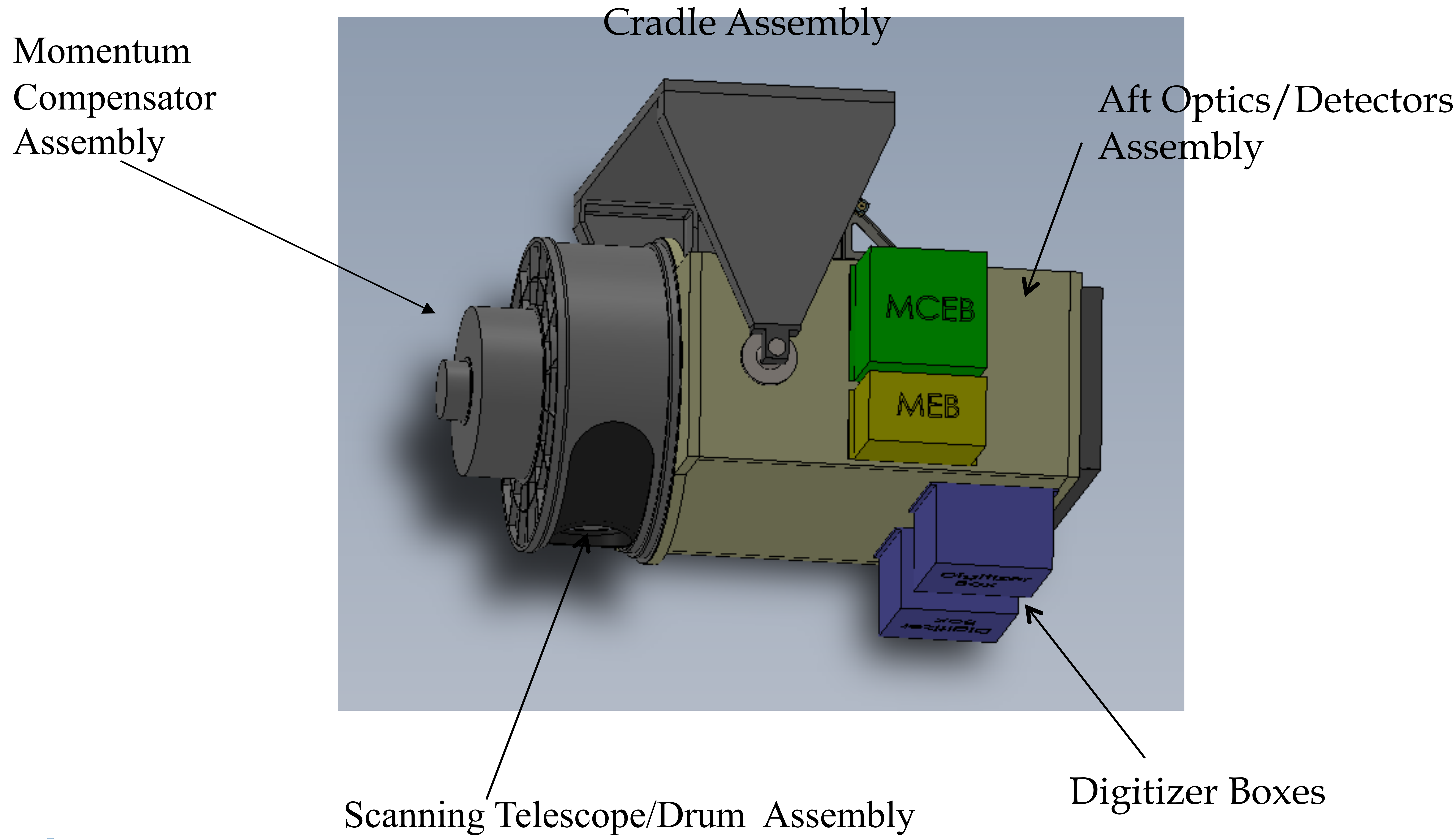
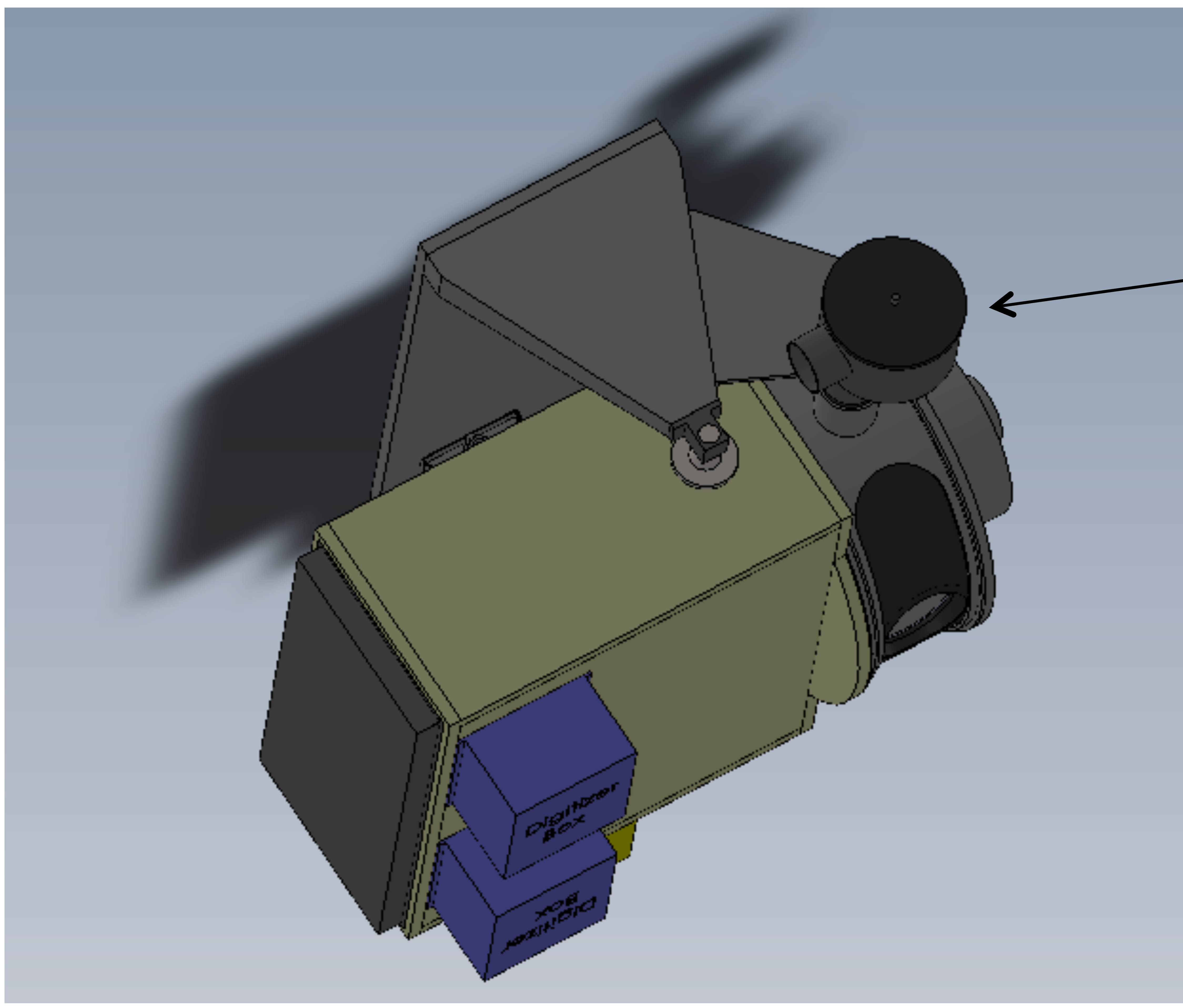


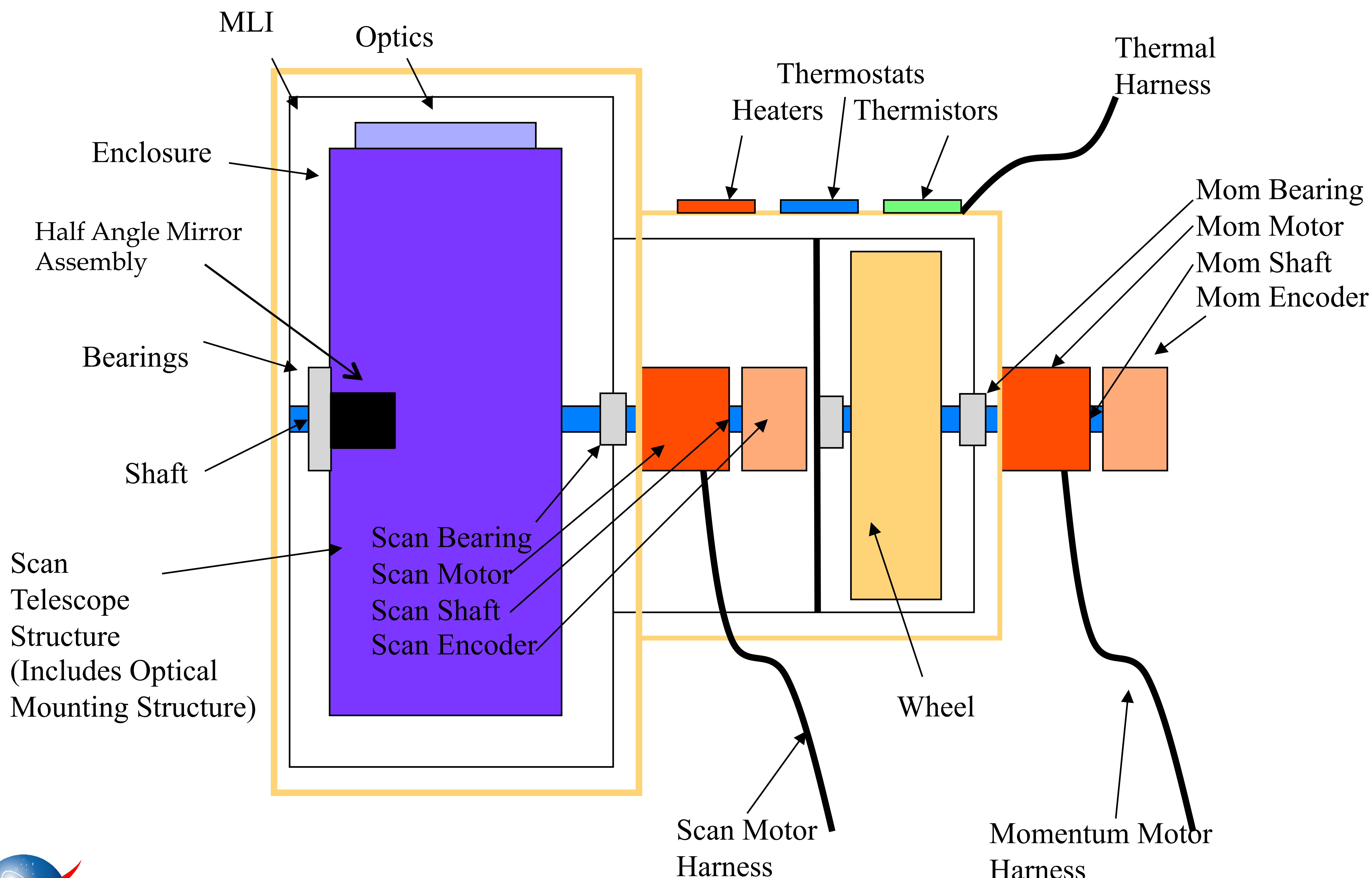
OCE2

Instrument Synthesis & Analysis Laboratory



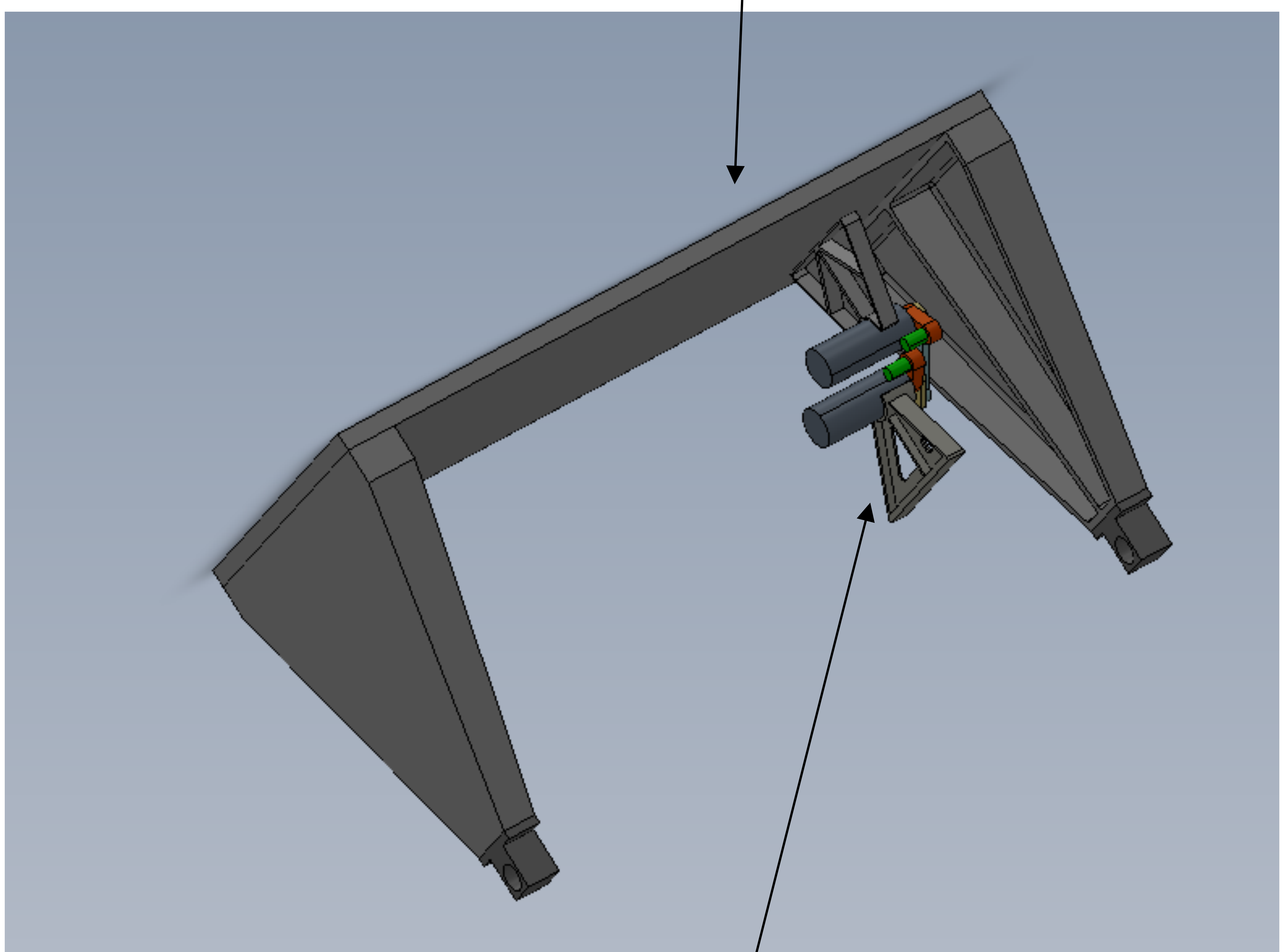
Scan Telescope and Momentum Compensation Notional Block Diagram

Instrument Synthesis & Analysis Laboratory



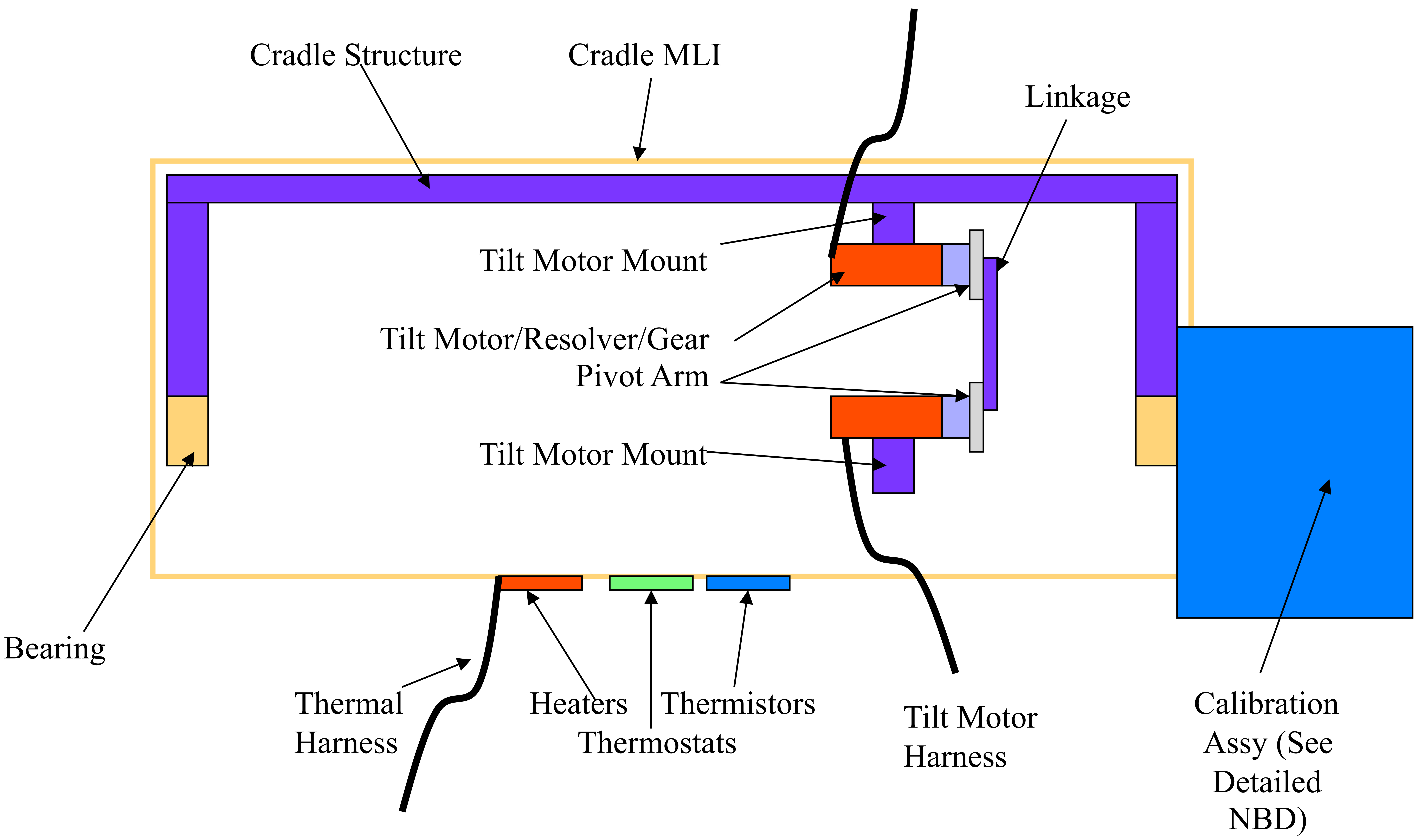
Cradle Assembly

Instrument Synthesis & Analysis Laboratory



Cradle Assembly Notional Block Diagram

Instrument Synthesis & Analysis Laboratory



Calibration Assy Notional Block Diagram (GOCECP) REPLACE

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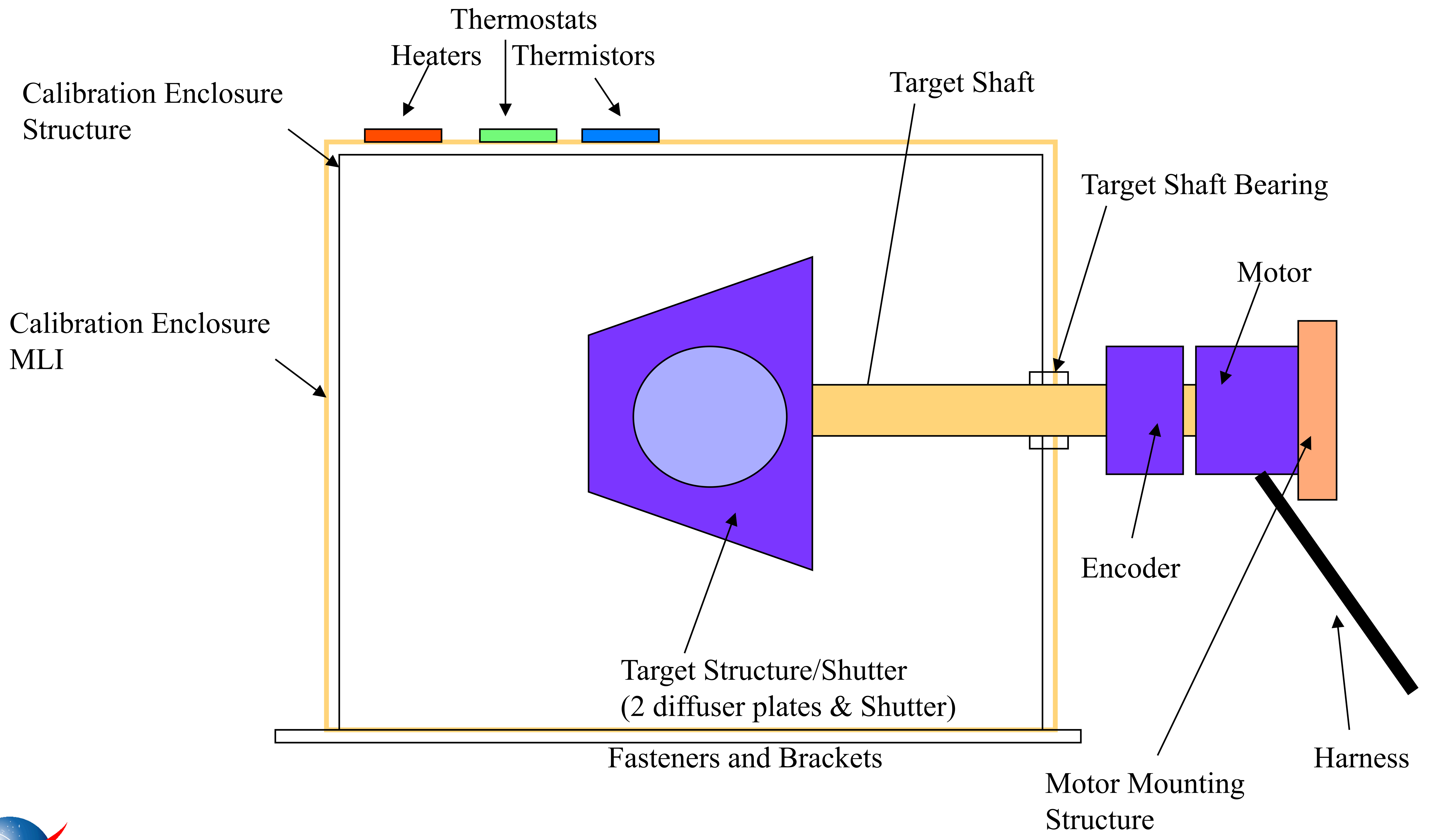

OCE2 Top Level Block Diagram

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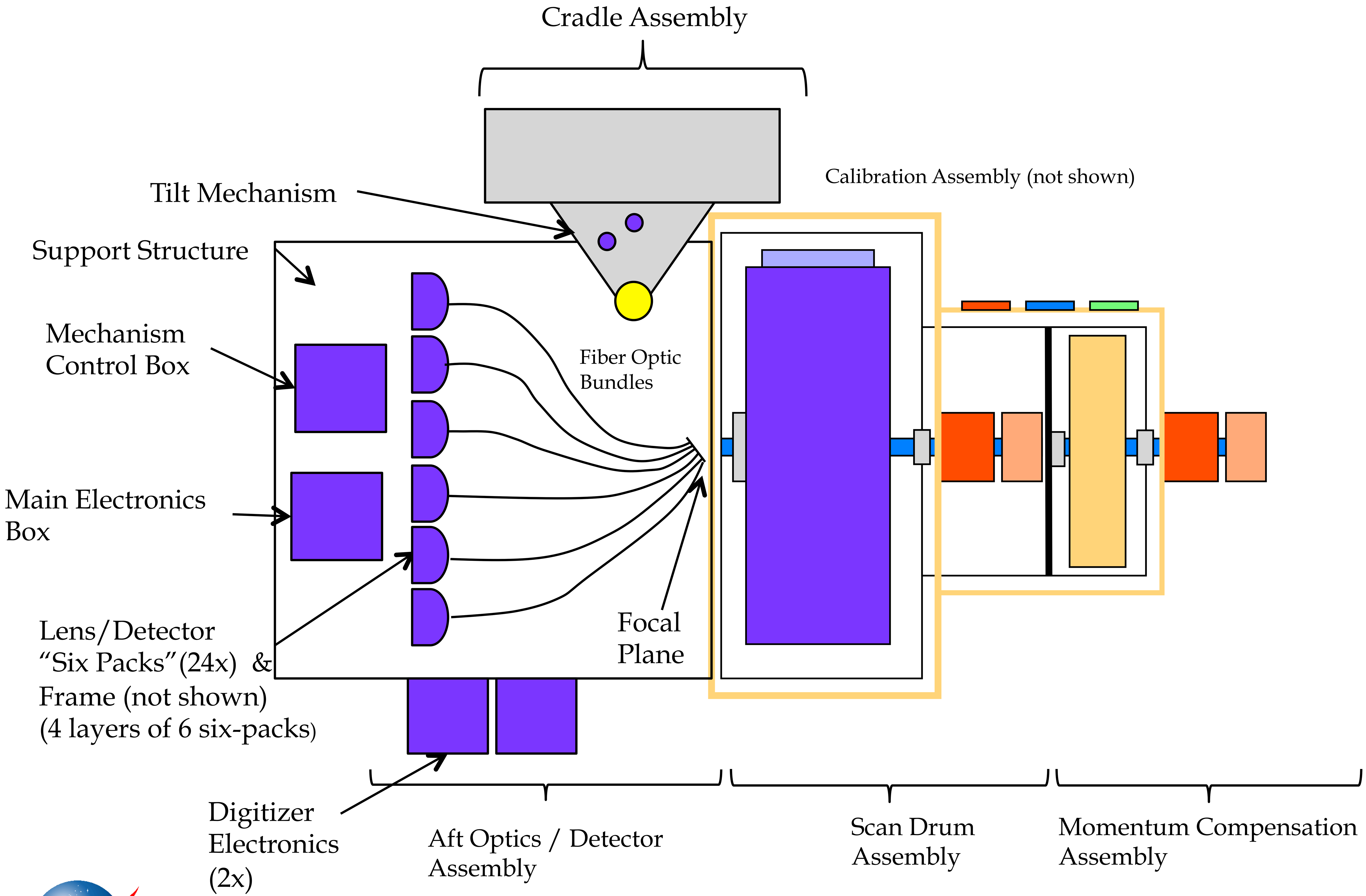
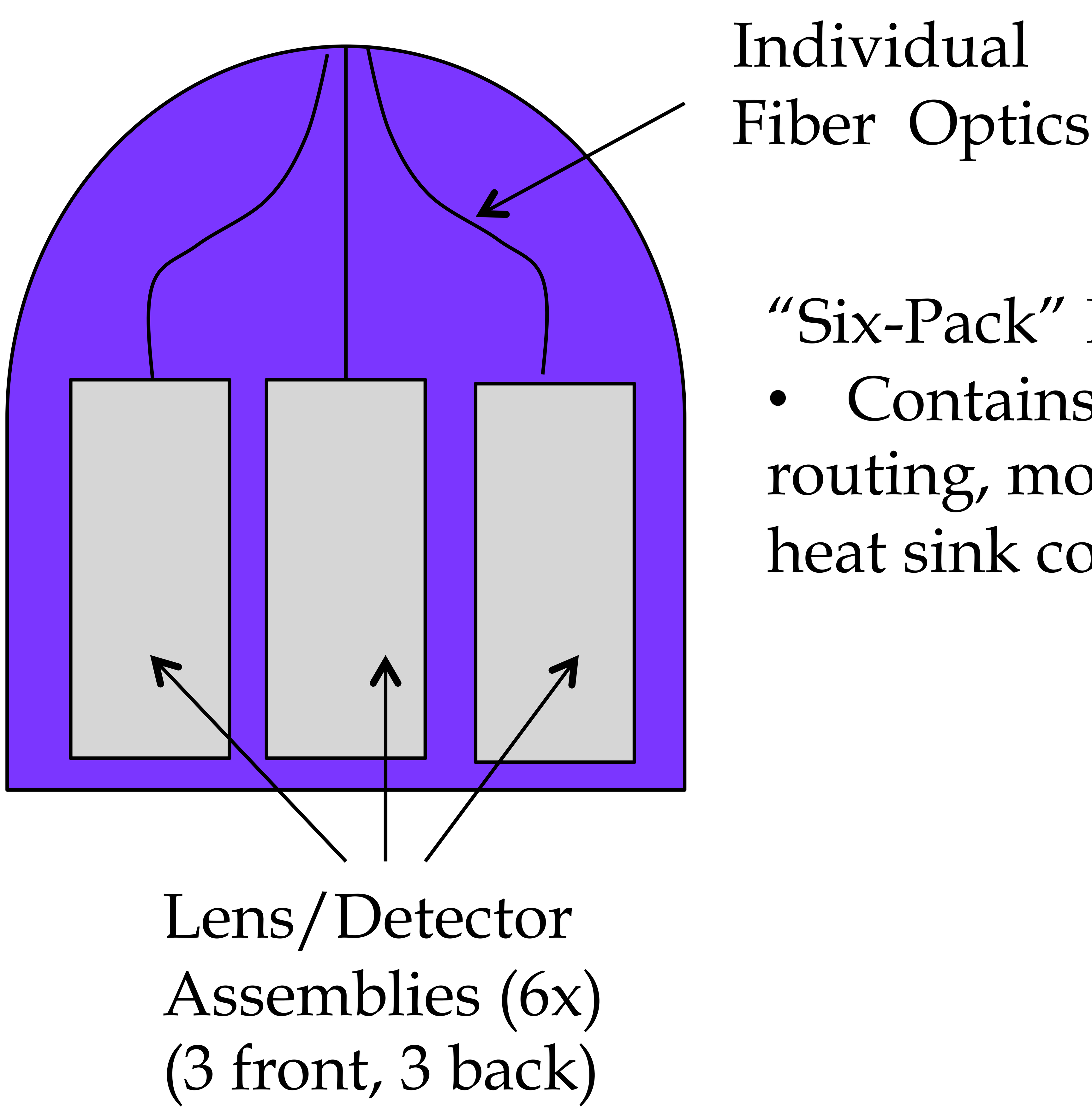


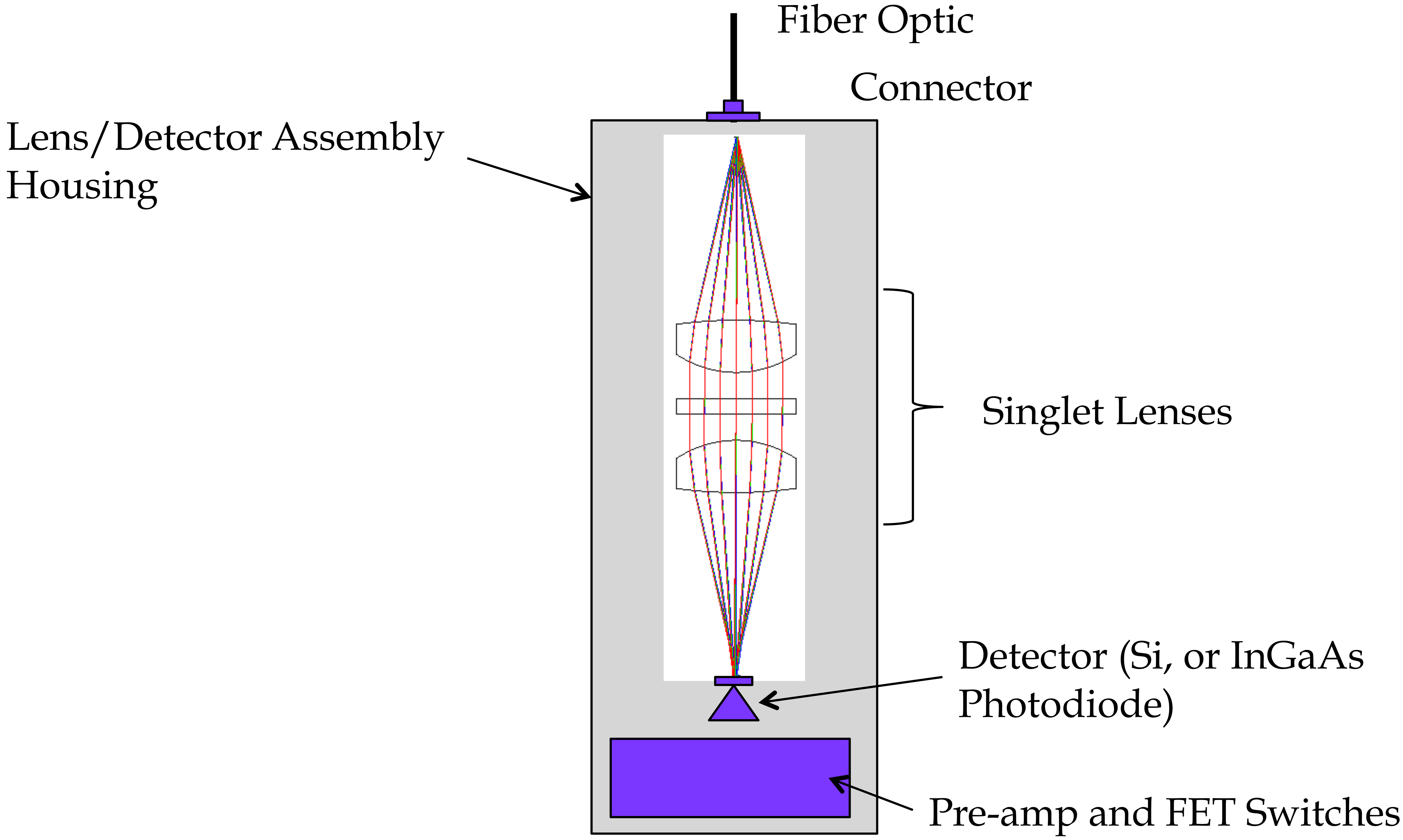
Lens/Detector Assembly “Six-Pack”



“Six-Pack” Mounting Plate

- Contains features for fiber routing, mounting to frame, heat sink connection

Lens/Detector Assembly



Driving Design Requirements

<table>
<tr><th>Requirement</th><th>Design</th></tr>
<tr><td>

Accommodate continuous scanning telescope

Effective Focal length (mm)	520.36
F/#	2.89
Plate scale	1 km / fiber core (0.8mm)
FOV	1° × 1°
Wavelength range (nm)	350 - 2400
Pupil Diameter (mm)	180

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- 0.620 m telescope assembly
  - Schmidt Plate
  - Primary Mirror
  - Fold Mirror
  - Half Angle Mirror
- Scanning Telescope Mechanism
  - Brushless DC Motor w/ redundant windings and controller
  - 369 rpm
  - 16 Bit Encoder
  - Rotating Mass ~19.6kg
  - 100% Duty Cycle
- Half Angle Mirror Mechanism
  - Brushless permanent magnet motor w/ redundant windings and controller
  - -184.5 RPM
  - 16 Bit Encoder
  - Rotating Mass ~0.2 kg
  - 100% Duty Cycle
- Momentum Compensation Mechanism
  - Brushless permanent magnet motor w/ redundant windings and controller
  - TBD RPM
  - Rotating Mass ~TBD kg
  - 100% Duty Cycle

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</table>

Driving Design Requirements

Requirement	Design

Fiber feed focal plane to optics detector assemblies
• 144 channels
• 800 um core fiber (40um cladding)
• Minimum bend radius 100 mm (4”)
	• Optic / Detector Assembly
	  • Singlet Lens
	  • Photodiode (1 per assembly; 138 Si, 6 InGaAs)
	  • Pre-amp and Fet Switches
	  • ~25mmx25mmx150mm
	• “Six-Pack”
	  • 2x3 mechanical module for 6 Optics/Detector Assemblies
	• Aft Optics/Detectors Structural Support
	  • Supports 24 “Six Packs”
	  • Provide structural features for routing/supporting fiber optic bundles

Tilt scanning telescope assembly +/-20 degree (forward/aft scanning) • Additional position to support calibration target observation	• Two stepper motor gear boxes with 12 bit resolvers • -20deg, 0 deg (calibration position), +20 deg position • No hardstops • Launch Lock (HOP actuator) cage instrument for launch

Driving Design Requirements

Requirement	Design

Daily Calibration	• Calibration Assembly
	  • 3 position actuator
	  • 2 positions for diffuser plate (solar illuminated)
	  • 1 closed position
	  • Perforated plate at entrance

Driving Assumptions

- **Spacecraft slews to position scanning telescope for monthly lunar calibration**
  - No additional ports included in instrument design to support lunar calibration
- **No onboard data processing beyond digitization and compression (in hardware) and typical data formatting and time-stamping (in software)**
  - Telemetry segmented into
    - Housekeeping
    - Science/Calibration
  - No provision within instrument for special processing of data slated for direct broadcast
- **Spacecraft discards / ignores science data outside areas of scientific value**
  - Dark side of orbit
  - > 70deg latitude
- **Spacecraft ACS hardware and Instrument mechanism position outputs are sufficient to meet instrument science data geo-location requirements**
  - R. Wesenberg provided a quick calculation of the pointing knowledge needs
    - He estimated that the knowledge needed to be 29arcsec for 1km channels and 5arcsec for the 250m channels (cumulative sum of error sources)
    - The Science Definition Team (SDT) is expected to confirm this assessment

Design Discussions

- **Implementing additional atmospheric channels with 250m resolution**
  - IDL will investigate the implementation of 32 channels with 250m resolution during the study extension
- **Auto adjustment of integration period**
  - Limited to 12 channels only
  - Implemented through FSW
- **Guidelines for implementing fiber optics documented in Backup charts**

Systems Summary
Part II

Preliminary Top-Level* Mass Summary
(no contingency included)

Ocean Color Experiment 2	Mass CBE (kg)	% of Total Mass
Scan Drum and Mechanism Assembly	44.6	23.3%
Scan Drum Assembly	41.4	21.7%
Scan Drum Mechanism Assembly	0.1	0.0%
Half Angle Mirror Assembly	1.0	0.5%
Half Angle Drive System	1.4	0.7%
Momentum Compensation Assembly	26.9	14.1%
Cradle Assembly	21.8	11.4%
Cradle Structure	16.4	8.6%
Tilt Mechanism Assembly	2.2	1.1%
Calibration Target Assembly	4.5	2.4%
Aft Optics/Detector Assembly	39.0	20.4%
Detector Array Assembly	15.8	8.3%
Digitizer Box	14.2	7.5%
Main Electronics Box	4.4	2.3%
Mechanisms Electronics Box	7.1	3.7%
Harness	**TBS**	-
Thermal Subsystem	23.6	12.4%
5% misc Hardware	9.5	5.0%
Total (+ 5% hardware and no margin):	**191.1**	**100.0%**

*this listing does not include all subassemblies, please refer to the final mass model (MEL) for a full summary

MEB Power

E-Box External Load	Power (W)
Detector and Amp Dissipation	145.0
Digitizer Electronics	82.0
Motors/Actuators (Scan Tel (12W avg), HAM (4W avg), Mom Comp (42W avg)	58.0
Mechanism Control (Scan Telescope, HAM, Mom Comp)	15.0
E-Box External Dissipation:	300.0
E-Box Boards	Power (W)
CPU Board + H/K	7.5
Thermal Control	28.0
E-Box Boards Dissipation:	35.5
E-Box Power Board Load	335.5
Converter % Efficiency	75
E-Box Converter Dissipation:	111.8
E-Box Dissipation:	147.3
Spacecraft Load	Power (W)
Additional Load(Tilt Mech & Cal Mech (30W pk, 0W avg):	0.0
Instrument Total:	447.3

MEB Size

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CCE Circuit Boards			Comments
Length	Width	Quantity	
8	6	5	Length/Width in inches
20.32	15.24		Length/Width in centimeters (1in = 2.54 cm)
Backplane:			
8	5	0.4	Backplane Length/Width in inches, Mass in Kg.
Board Mass Total:	2.9	Kg	My Metric: 0.5 Kg each 8"x6" board
	6.4	lbs	1lb = 0.45359237 Kg, 1Kg =2.204Kg
			1 in = 0.0254 meters = 2.54cm = 25.4 mm, 1 meter = 39.370 in
Electronics Box			
Depth (D)	Height (H)	Width (W)	
9	7	6	
22.86	17.78	15.24	(centimeters). Divide by 100 for meters
Surface Area Total	0.21		Area = 2(DH+HW+WD)/10000 square meters
Wall thickness (mm)	2.50		millimeters. Divide by 1000 for meters
Density (Aluminum)	2,700.00		Kg/Meter3
Housing Mass:	1.4	Kg	(Mass = Volume x Density. ie Area x Thickness x Density)
	3.1	lbs	
Box Mass Total:	4.3	Kg	(ie. C8+C19)
	9.5	lbs	(ie. C9+C20)

Digitizer Card Power Calculations

- Sample n Hold = 135mW x 8 = 1080mW
- MUX = .01uW
- ADC = 1W
- FIFO = 2.5W
- Total per card = 4.5W per card
- 9 cards per box
- 2boxes
- Total per box = 41W
- Total Digitizing Power = 82W

Digitizer and Mechanisms Boxes Size

CCE Circuit Boards			Comments
Length	Width	Quantity	
8	6	9	Length/Width in inches
20.32	15.24		Length/Width in centimeters (1in = 2.54 cm)
Backplane:			
8	9	0.8	Backplane Length/Width in inches, Mass in Kg.
Board Mass Total:	5.3	Kg	My Metric: 0.5 Kg each 8"x6" board
	11.6	lbs	1lb = 0.45359237 Kg, 1Kg =2.204Kg
			1 in = 0.0254 meters = 2.54cm = 25.4 mm, 1 meter = 39.370 in
Electronics Box			
Depth (D)	Height (H)	Width (W)	
9	7	10	
22.86	17.78	25.4	(centimeters). Divide by 100 for meters
Surface Area Total	0.29		Area = 2(DH+HW+WD)/10000 square meters
Wall thickness (mm)	2.50		millimeters. Divide by 1000 for meters
Density (Aluminum)	2,700.00		Kg/Meter3
Housing Mass:	1.9	Kg	(Mass = Volume x Density. ie Area x Thickness x Density)
	4.3	lbs	
Box Mass Total:	7.2	Kg	(ie. C8+C19)
	15.9	lbs	(ie. C9+C20)

Data Rates

Readout Data Rate:

- Assume 144 channels per scan
- 30 μs Integration Period
- 14 bits each channel

⇒ **Readout Data rate** ~ (102deg/360deg) (144 channels x 14 bits/channel)/30μs ~ **19.04Mbps**

⇒ **Assume 50% for daylight only** ~ **9.52Mbps** (avg.)

⇒ Assume data collection between **$\pm$ 70deg** latitude

⇒ **Orbital Average Data Rate** ~ 9.52Mbps x (140deg /180deg) ~ **7.4Mbps**

⇒ 7.4Mbps x (3600sec/hour) x 24hour/day = **639.36Gbits/day**

Cost Assumptions (1 of 3)

Instrument Life Cycle

• Phase B Start	6/2014
• Instrument PDR	3/2015
• Instrument CDR	6/2016
• Start Integration	11/2016
• Payload Environment Review	8/2017
• Delivery to s/c or observatory	6/2018

Number of fully integrated flight units to build and cost

• Fully Integrated Flight Units	**1**
• **Fully Integrated Flight Spare Units**	**0**
• Fully Intergrated Engineering Test Units (ETU)	**0**
• Fully Intergrated Engineering Development Units (EDU)	**1**

Cost Assumptions (2 of 3)

Build Assumptions:

- Out of House (use non-proprietary contractor rates)

Cost Assumptions

- 2012 constant year dollars

Class of Mission

- Class B electronics

Throughput or Purchased Item(s)

- None

Cost Assumptions (3 of 3)

- Detectors is using SEER-H and Grassroots to estimate Detectors costs
- Firmware for FPGAs will use Grass Roots. The methodology will be in the electrical presentation
- FSW Software is using SEER-SEM
- Additional Hardware Costs
  - FSW Ground Support Equipment (GSE) – Grass Roots to estimate
  - Ground Support Equipment (GSE) - 5% of Estimated Instrument Hardware Cost to Estimate
  - Environmental Testing - 5% of Estimated Instrument Hardware Cost
  - Engineering Test Unit (ETU) – 10% of Estimated Instrument Hardware Cost Component Level
  - Flight Spares - 10% of Estimated Instrument Hardware Cost
  - Instrument to S/C Bus Integration & Test - 5% Estimated Instrument Hardware Cost. Typically Included in WBS 10.0

Recommended Future Work

- **Continued evaluation of fiber optic layout**
  - Include results of testing of flight fiber optics materials
- **Search for lowest power part options for detector readout and digitization electronics**
  - Small reduction can yield large saving given the large number of repeated components
- **Define requirements for processing of direct broadcast data**
- **Refine requirements for regions of valid science data acquisition**
  - More accurately define data volume
- **Reevaluate implementation of Momentum Compensation Mechanism**
  - Incorporate into Half Angle Mirror Mechanism?
  - Reduce number of cycles of Momentum Compensation Mechanism (larger wheel)
  - What did SeaWifs do?
- **Evaluate having S/C perform +/-20 deg tilt and eliminate tilt mechanism**
- **Re-optimize Optics (altitude change, depolarizer)**
- **Consider alternate design for Half Angle Mirror**
- **Investigate best approach for use of AR coatings**
- **Investigate radiator configurations (flat vs pocketed)**

Conclusions

- **Larger number of detector channels leads to high power consumption for normal operations**
  - Estimated at ~448W
  - Will only grow with addition of more channels
  - Drives large radiators
- **Number of cycles on Scan Telescope, Half Angle Mirror and Momentum Compensation Mechanisms is very high**
  - 3.6 Billion, 1.8 Billion, and 14.6 Billion cycles respectively
  - Life testing will be a challenge
- **Integration and Test of Optics/Detector and Assemblies Fiber Optics may be tricky**
  - Custom alignment for each fiber optic and Optic/Detector assemblies
  - Potential accessibility issues

BACKUP CHARTS

Fiber Receiver Optics (Doublet)

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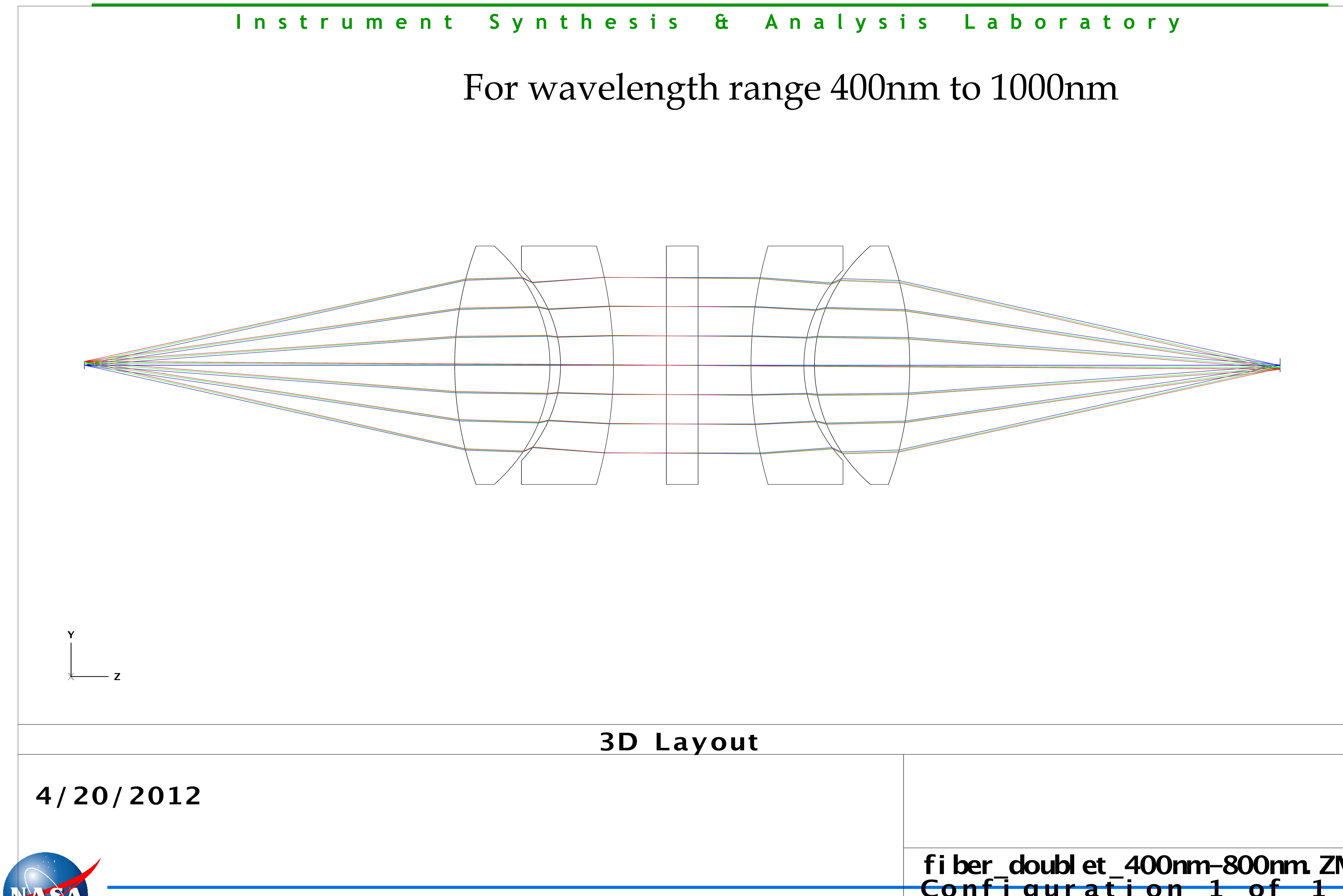
For wavelength range 400nm to 1000nm



Fiber Optic Discussion

- **The specific fiber lot needs to be tested for attenuation**
  - To quantity the sensitivity to bending and the limit on bend radius
- **On a sensitive photon counting instrument, they can accept up to a 2” bend radius without loss (Atlas)**
  - This was a 400micron fiber; our core is 2x as big (800micron)
  - We agreed to limit our bend radius to a minimum of 4” (102 mm)
- **Various types of connectors exist for the fiber interface to the lens/detector assemblies**
  - Hard stops or can include lenses in connectors
  - Need to determine f# of end of fiber using a hardstop
  - Fiber should remain straight for 4 to 6 inches beyond connector before introducing first bend to minimize stress on fiber at connector where it is rigidly mounted
- **Fiber bundles should be tied down every 4” but not rigidly**
  - Fibers need to be allowed to flex (minimize stress on fibers)
  - Suggest Delrin trays for bundle tracks with zip-tie fasteners around house (not directly contacting fibers)
- **Fibers can be twisted around a central core completing a revolution every 18”**
- **Fibers not expected to be sensitive to on-orbit vibration environment**
  - Tested with launch vibrations

Fiber Optics Discussion

- **Thermal gradients and bulk temperature transitions will change the attenuation as well, so we need thermal control**
  - -40 to +80C is the range that has been tested
  - Want to keep the fibers as warm as possible within acceptable heater power allocation
  - Stability +/-5
  - Unjacketed fiber is considered more thermally stable
- **Radiation Darkening of fibers**
  - Material will be a doped fused silica but vendor will probably not reveal the doping formula
  - Pretty benign <10Krad
  - Can be minimized by maintaining thermally stable environment
- **Options for fixing position of fibers at the focal plane need to be studied**
  - Laser fusing fiber cladding together mentioned as a possibility
  - Can use an epoxy to pot the fibers together
  - Assume it can be done
- **Application of anti-reflective coatings to ends of fibers is common practice and processes are understood**
  - This needs to be studied for OCE2 since the fibers need to be gathered at the focal plane and polished before applying AR coating. This approach implies that the AR coating is broadband unless rows can be masked to allow different AR coatings to be applied. Need to determine if fibers can be gathered at the focal plane after individually polishing and coating them.